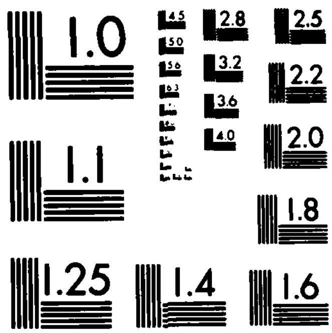
AD-A131 318 FEED (FIELD EXPLOITATION OF ELEVATION DATA) EVALUATION 1/1
(U) GEORGIA INST OF TECH ATLANTA ENGINEERING EXPERIMENT
STATION N L FAUST ET AL. AUG 83 ETL-0322

UNCLASSIFIED DAAK70-81-F-0491 F/G 9/2 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ETL-0322

12

FEED evaluation

N. L. Faust
M. J. Rowan
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

August 1983

83 08 12 001

Prepared for
U.S. ARMY CORPS OF ENGINEERS
ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

E
T
L

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
ETL

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ETL-0322	2. GOVT ACCESSION NO. AD-A131318	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FEED Evaluation		5. TYPE OF REPORT & PERIOD COVERED Technical Report Sept 1981 – June 1982
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) N. L. Faust M. J. Rowan		8. CONTRACT OR GRANT NUMBER(s) DAAK-70-81-F-0491
9. PERFORMING ORGANIZATION NAME AND ADDRESS Georgia Institute of Technology Engineering Experiment Station Atlanta, Georgia 30332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, Virginia 22060		12. REPORT DATE August 1983
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) digital elevation FEED terrain		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report is an evaluation of the Field Exploitation of Elevation Data (FEED) as it relates to the expressed objectives. Software and hardware were considered.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This document was generated under Contract DAAK70-81-F-0491 for the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 22060 by the Georgia Institute of Technology, Engineering Experiment Station (EES), Atlanta, Georgia 30332 and submitted by EES as A-3067. The Contracting Officer's Representative was Mr. William Veigel.

A

CONTENTS

TABLES

FEED EVALUATION

1.0 INTRODUCTION

1.1 Purpose of Report

This report on the U.S. Army Engineer Topographic Laboratories (USAETL) Field Exploitation of Elevation Data (FEED) system is an evaluation by the Georgia Institute of Technology Engineering Experiment Station (EES). The evaluation is based on information gathered from interviews with military officers and troops, Army civilian employees, and defense contractors and EES's experience with FEED. Additional information came from previously published FEED-related research, Army field manuals, and questionnaires. Emphasis is placed on three major topics: the FEED demonstration tour and its objectives; technical aspects of the hardware/software system; and alternatives and recommendations for FEED.

The task of the U.S. Army Engineer Topographic Laboratories USAETL ~~(ETL)~~ (USAETL) is to develop topographic and terrain analysis products to support the functions of the Field Army. Concurrently, ETL must evaluate and determine the form in which these products can evolve to the battlefield. The 1980-1984 Department of the Army Consolidated Topographic Support Program (DACONTSP) had expressed an interest in automated topographic support capabilities to rapidly produce terrain-related cartographic products. It is within this environment that the FEED system has been developed.

1.2 FEED Background

The original impetus for the FEED system dates back to the early production of digital elevation data bases (DEDB) by the Defense Mapping Agency (DMA) and ETL-sponsored research on data storage technologies and automated cartography. The research demonstrated that mathematical models could be defined that "reasonably" approximate the true surface form and provide for reduced data storage requirements. A detailed description of the techniques is given by Jancaitis and Junkins.[1]

In-house research at ETL also produced software for accomplishing terrain analyses (line of sight, terrain masking, etc.) on DEDB Level I data provided by DMA. In 1978 the FEED program was initiated at ETL to "develop and test an experimental militarized computer interactive graphics system with the capability of exploiting digital topographic data based in a tactical environment."[2]

The program was managed by the Topographic Developments Laboratory at ETL. The Electromagnetics Compatibility Analysis Center (ECAC) was requested to assemble and test such a ruggedized computer system and to modify existing ETL software so that it would operate on the new system. During the implementation period, ETL lost some of its in-house capability and more reliance was placed on ECAC personnel. The system was initially delivered to ETL in June 1980 for preliminary demonstrations at ETL's 60th anniversary observance. It was then returned to ECAC in July for further development. In December 1980 the system was delivered to ETL with a limited capability for demonstrations. ETL installed the system in a van. In March 1981, the van traveled to Fort Monroe, Virginia, for its first in a series of demonstrations. Personnel from the Illinois Institute of Technology Research Institute (IITRI), working under an ECAC contract, supported the FEED system. Their support consisted of 1) correcting existing software problems encountered in the field, 2) implementing new hardware (a militarized printer/plotter), and 3) performing the software development needed to utilize the new equipment and operate in a military grid coordinate system.

In April 1981, technical responsibility at ETL for the FEED project was transferred to the Geographic Sciences Laboratory (GSL). The ECAC continued to supply the contractor support for the FEED system until 1 October 1981. At that time, ECAC withdrew their support and the support of their contractor from the project. Georgia Tech EES assumed the role of the FEED support contractor. From 1 October 1981 to the present, EES has been responsible for 1) maintenance support of the FEED system in demonstrations and field operation participation, 2) software modification to correct errors or enhance capability, and 3) an evaluation of the FEED demonstration program and the FEED software.

1.3 FEED Components

The four general components of the FEED system are 1) the source elevation data, 2) a polynomial terrain model, 3) hardware configuration, and 4) product-producing software.

1.3.1 Source Data

Source data for the FEED system are provided by the Defense Mapping Agency (DMA), which has been producing digital terrain elevation data (DTED) for approximately twenty years, to be used originally for special-purpose mapping functions. It became readily apparent, however, that the utility of the data went well beyond the original purpose, both inside and outside the Department of Defense. A set of elevation data on a tape (DTED) can be conceptualized as a grid covering an area, with elevations recorded for discrete geographic locations represented by grid intersections, and the data stored on a computer-readable medium. The DMA collection efforts vary in resolution (horizontal spacing between data points), but the standard Level I product is approximately 100 meters horizontally and 50 meters vertically. Overall locational accuracy for the Level I data is comparable to that of the 1:250,000 map sheets.[3] Level II data (12.5 meters horizontally), comparable to 1:50,000 map sheets, exist for a limited number of areas in the world.

1.3.2 Source Storage

The second component of the FEED system is the polynomial terrain model, a technique that describes the structure of a topographic surface as a mathematical equation. An elevation value for any point on that surface can be derived by using the equation and appropriate input parameters. An original impetus for the modeling techniques in FEED was to compress the amount of source data. Stated simply, at 100 meters resolution the amount of data in a worldwide data base is tremendous. The polynomial terrain model, in contrast, stores only a small portion of the data points along with coefficients for the equation that describes the surface.

These compressions are produced by representing N x N elevation data points, each normally stored in 2 bytes, as a surface equation whose coefficients can be contained in 6 bytes. The normal data volume for an N x N point set is 2N x 2N or $4N^2$ bytes. By using a polynomial, the same data are represented by 6 bytes. The compression ratio is then $R = 4N^2/6$. If N = 10, then R = 66.6.

1.3.3 Hardware

The current hardware configuration of the operational FEED system consists of

1) ROLM 1602A processor (AN/UYK-19(U))
2) CDC 80 megabyte disk drive and controller
3) Miltope 800 bpi magnetic tape unit and controller
4) Tektronix RE4012 graphics display terminal and attached Tektronix 4631 hard copy unit
5) Versatec 7200A electrostatic printer/plotter
6) Miltope floppy disk units

A digitizing tablet was purchased, but incompatibility between mil-spec and commercial interface boards prohibited its installation. All of the equipment with the exception of the CDC 80 Mb disk is ruggedized and, therefore, fieldable.

1.3.4 Software

The final system component is the application software, producing five major types of graphics output: 1) line-of-sight, 2) terrain masking, 3) contour plots, 4) 3-dimensional (oblique), and 5) perspective views. For each of the analysis modules the key component is an elevation profile. Contour plots are generated by connecting data for parallel profiles; terrain-masking plots connect profiles radiating from a central point; and perspective and oblique plots use parallel profiles moving away from a viewer location. Examples of output and engineering theory for each of the above application programs are given in two reports.[4,5]

2.0 EVALUATION OF FEED DEMONSTRATIONS

2.1 Goals of Tour

The most appropriate way to evaluate the success or failure of any mission is to compare the results against the stated mission objectives. Documents relating to FEED stated the following objectives:

1) "...familiarize commanders and their staffs with the kinds of tactical computer graphics that can be produced in the field with existing technology."[6] This goal was to be accomplished using currently available laboratory equipment.

2) "...developing from potential users, statements of need and performance to guide ETL's continued exploratory development of computer-assisted terrain analysis systems."[7]

2.2 Format of Demonstrations

The tour of CONUS began with a demonstration at Fort Monroe, March 10-13, 1981. At any other bases that responded favorably, ETL made preliminary presentations on FEED capabilities. Discussions were also held to determine where in the FEED schedule a demonstration could be held and what arrangements were necessary to provide space and facilities for the FEED van. Normally after this meeting, a liaison person was selected and an announcement was sent to base personnel stating the FEED capabilities and its schedule while on the base. Interested personnel were then allowed to sign up for time slots for a presentation.

On the agreed-upon date the FEED van was located at the base, and normal setup procedures and liaison meetings occupied most of the first day. One or more of the base personnel were trained on the FEED hardware to be able to assist in the demonstrations. This exercise normally took less than one day. Demonstrations for the following days generally occurred hourly between 0800 and 1700 with 5 to 10 persons in each session.

Each session featured a presentation of the overall FEED concept. This presentation related to the various data types capable of being used to create FEED output. Also discussed were the potential users of these outputs. Next, the hardware of the existing FEED system was detailed. During the hardware description, a plot was being generated on the Tektronix display CRT showing one of the types of analysis that can be performed using the system. A discussion of all five analysis techniques followed.

The discussion was aided by examples of each type of analysis displayed on a bulletin board. The discussion concluded with explanations of the other types of terrain analysis systems that are currently being developed at ETL. Questions were then fielded as time permitted. The viewers were asked to fill out the FEED questionnaire (appendix A) and to come back for more detailed answers as their time and the FEED schedules permitted.

In cases where the number of people signed up to visit the FEED van was small, the presentations were expanded and more time was available for user familiarization and the fielding of questions.

2.3 Satisfaction of Goals

Several hundred persons viewed FEED during the demonstration tour and approximately 10 percent completed the questionnaire. The overall results and cross-tabulations are shown in tables 1-4. These results, combined with other materials and comments made during demonstrations, were the basis for determining the extent that the FEED tour achieved its stated goals.

The concensus based on the data gathered is that the FEED tour most successfully accomplished the goal of familiarizing commanders and their staffs with the capabilities of automated terrain graphics. First, the demonstrations were presented in such a manner as to expose the viewer to a range of application areas. No single application was emphasized; rather, diversity was stressed. The terrain-masking algorithm displayed how one analysis concept could be applied to several tactical problems.

The fact that the viewers appreciated the potential applications is supported by the questionnaire responses. Ninety percent stated it would be used in the accomplishment of their mission and, equally important, it was viewed as useful across the areas of training, war-gaming, mission planning, and mission execution. War-gaming had the lowest favorable response at 65 percent, while the others were approximately 80 percent and above. Finally, all field grade officers and above stated that it would be used in their mission accomplishment.

TABLE 1. Questionnaire data - Total responses

	Areas						How Employed					
Survey Question	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other	Terr Apprec	Sensor Empl	Intelli-gence	Weapons Siting	Flight Ops	Other
Positive Responses	64	56	46	67	59	10	62	41	61	37	41	18
Total Responses	71	71	71	71	71	71	71	71	71	71	71	71
Percent Positive	90.1	78.9	64.8	94.4	83.1	14.1	87.3	57.7	85.9	52.1	57.7	25.4

	Graphics								
Survey Question	Line of Sight	Terrain Masking	Contour	Perspec-tive	Oblique	Military Features	Move-ment	Site Selec-tion	Other
Positive Responses	62	64	57	50	57	49	43	54	11
Total Responses	71	71	71	71	71	71	71	71	71
Percent Positive	87.3	90.1	80.3	70.4	80.3	69.0	60.6	76.1	15.5

	Location												
Survey Question	Train-ing Sites	Battle-field	EAC	Corps	Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty	Other
Positive Responses	46	44	21	38	37	27	16	47	27	19	15	17	24
Total Responses	61	61	60	60	60	60	60	60	60	60	60	60	60
Percent Positive	75.4	72.1	35.0	63.3	61.6	45.0	26.7	78.3	45.0	31.7	25.0	28.3	40.0

TABLE 2. Questionnaire responses - Field grade officers and above

Survey Question	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other	Terr Apprec	Sensor Empl	Intelli-gence	Weapons Siting	Flight
			Areas						How Employed		
Positive Responses	26	22	19	24	22		22	17	21	17	18
Total Responses	26	26	26	26	26		26	26	26	26	26
Percent Positive	100	85.0	73.0	92.0	85.0		85.0	65.0	81.0	65.0	69.0

Survey Question	Line of Sight	Terrain Masking	Contour	Perspec-tive	Oblique	Military Features	Move-ment	Site Selec-tion
					Graphics			
Positive Responses	18	19	16	14	17	16	12	19
Total Responses	26	26	26	26	26	26	26	26
Percent Positive	69.0	73.0	61.0	54.0	65.0	61.0	46.0	73.0

Survey Question	Train-ing Sites	Battle-field	EAC	Corps	Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty
					Location							
Positive Responses			6	12	10	9	4	13	11	2	4	4
Total Responses			26	26	26	26	26	26	26	26	26	26
Percent Positive			23.0	46.0	38.0	35.0	15.0	50.0	42.0	8.0	15.0	15.0

TABLE 3. Questionnaire responses - Intelligence

Survey Question	Useful	Training	Areas War Gaming	Mission Planning	Mission Exeq	Other	Terr Apprec	Sensor Empl	How Employed Intelli-gence	Weapons Siting	Flight Ops	Other
Positive Responses	27	25	16	28	17	3	37	17	24	17	11	3
Total Responses	30	30	30	30	30	30	30	30	30	30	30	30
Percent Positive	90	83	53	93	56	10	90	57	80	57	37	10

Survey Question	Line of Sight	Terrain Masking	Contour	Perspec-tive	Graphics Oblique	Military Features	Move-ment	Site Selec-tion	Other
Positive Responses	28	28	27	26	12	23	18	21	3
Total Responses	30	30	30	30	30	30	30	30	30
Percent Positive	93	93	90	87	40	77	60	70	10

Survey Question	Train-ing Sites	Battle-field	EAC	Corps	Location Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty	Other
Positive Responses	19	11	7	15	10	7	5	17	10	10	5	9	11
Total Responses	27	27	27	27	27	27	27	27	27	27	27	27	27
Percent Positive	70	41	26	56	37	26	19	63	37	37	19	33	41

TABLE 4. Questionnaire responses - Engineering

	Areas						How Employed					
Survey Question	Useful	Training	War Gaming	Mission Planning	Mission Exeq	Other	Terr Apprec	Sensor Empl	Intelli-gence	Weapons Siting	Flight Ops	Other
Positive Responses	9	5	6	9	8	4	8	4	7	4	3	4
Total Responses	10	10	10	10	10	10	10	10	10	10	10	10
Percent Positive	90	50	60	90	80	40	80	40	70	40	30	40

	Graphics								
Survey Question	Line of Sight	Terrain Masking	Contour	Perspec-tive	Oblique	Military Features	Move-ment	Site Selec-tion	Other
Positive Responses	8	7	9	6	8	7	6	8	4
Total Responses	10	10	10	10	10	10	10	10	10
Percent Positive	80	70	90	60	80	70	60	80	40

	Location												
Survey Question	Train-ing Sites	Battle-field	EAC	Corps	Div	BDE	Other	TOC	Engr	Avia-tion	Signal	Arty	Other
Positive Responses	4	5	2	6	7	4	2	8	5	1	3	2	2
Total Responses	9	9	9	9	9	9	9	9	9	9	9	9	9
Percent Positive	44	56	22	67	78	44	22	89	56	11	33	22	22

2.4 Demonstration Difficulties

The FEED application software appears not to have been fully tested prior to the tour, so that errors frequently surfaced. This untested condition was more prevalent during the exercises such as HELBAT, where participants requested specific products, than it was in demonstrations where precalculated scenes were displayed. The reason lies in the fact that FEED provides the user with numerous options regarding scene content and viewing geometry so that the permutation of combinations for testing increases rapidly. Many software errors have been corrected during the tour; however, others still remain.

The FEED system hardware encountered numerous difficulties on the tour that were related to environmental conditions and the rigors of cross-country travel. The FEED travel logs show system crashes as a common occurrence. Most reliability problems were related to the CDC disk drive. It is a nonruggedized component and was not designed for operation in the FEED demonstration environment. Vendor maintenance was required on the device. Humidity caused problems at MacDill AFB, Florida, and during the HELBAT exercises at Fort Sill, Oklahoma. It should be noted that the humidity buildup at Fort Sill occurred during several continuous days of very heavy rain. System startup was difficult, but demonstrations were not impacted. Finally, the floating-point processor failed because of temperatures in the Fort Hood, Texas, sun that were much higher than mil-spec standards. The ROLM Corporation replaced the board.

In summary, FEED did not perform as a reliable fieldable system. However, only rarely did system errors directly affect a demonstration, and in such cases presentations were made using previously generated hardcopy products. Viewers did not appear to have adverse negative reactions.

An evaluation of the goal of developing, from users, statements of need and performance does not provide a clear answer. If the goal of the tour was solely to generate formal requirements documents, then the demonstration tour was unsuccessful. If the FEED tour can be viewed as a step in a continuing education process in the utility of digital elevation data and automated terrain analysis, then indicators of partial success exist. In view of these two statements it must be emphasized that as a direct result of the FEED tour, the Digital Terrain Analysis System Letter of Agreement was signed and funding made available.

To be able to state system performance specifications requires an in-depth user understanding of system attributes and components. The cognitive and physical processes of extracting information from standard maps is familiar to users, but FEED, in contrast, has introduced a new set of variables. Data resolution and terrain modeling, for example, need to be understood and evaluated by potential users and combat developers.

Normal demonstrations lasted only 30 to 45 minutes, providing enough time to briefly describe the FEED hardware and discuss sample plots of each type of analysis that could be generated using the FEED system. The demonstration was planned to allow time for questions and answers at the end of each session. The schedule did not allow time for potential users to receive hands-on instruction for using the system or to develop analysis over a region of special interest. Because of time constraints, the base-supplied military operators were taught only to execute the programs and not how to set up an analysis. Interaction with potential users is necessary in all phases of design and implementation of a successful analysis system. A 30- to 40-minute demonstration of an analytic technique, EES feels, is not sufficient to enable a potential user to evaluate the effectiveness of that technique.

The short time allocated to each site visit (3-4 days) was not sufficient to generate a consensus of usability by site personnel. In many cases the demonstrations occupied the FEED personnel full-time for the period that the system was at the site. There was little or no time for interested personnel to come back informally to ask questions about the system.

In the original plan a member of the ETL staff was to make a follow-up visit within days of the demonstration tour. This visit was to answer lingering questions on the FEED system, to gather comments as to the usefulness of the FEED system to the military units at the site, and to assist the site personnel in formalizing any statements of need for digital elevation data that might have surfaced because of the demonstrations. Since the planned follow-up visits did not occur, there was no coordination of needs of the various units, and any user suggestions as to how the demonstrations could be made more meaningful were largely lost.

There is a decisive interest in the FEED and its products although no formal requirement has been generated. Many respondents noted on the questionnaires a willingness to work for the inclusion of digital elevation data and FEED-like capabilities in requirements. Some personnel specifically requested the assistance of ETL in the endeavor. Moreover, Fort Bragg, North Carolina, formally requested the FEED software for extended testing and evaluation. The Human Engineering Laboratory wanted FEED to return for future testbed exercises. Other organizations, such as FORSCOM, want more technical information in order to evaluate its potential applications.

The questionnaire gives only limited insight into the respondents' perceptions of role and accuracy. One reason is that the accuracy question was not associated with any specific role option. Essentially, FEED is a scale-independent system; a positive design approach in the opinion of EES but related to the role dilemma. First, FEED can process its elevation data at any resolution, and second, it can output these results at any user-specified scale. These conditions enable FEED to generate a broad overview scene of a large area or a detailed analysis from a hypothetical forward observer location. Correspondingly, accuracy requirements change with the role definition and scale. Nevertheless a few generalizations can be made: 1) The median desired accuracy is 10 meters; 2) Engineers generally have the more precise requirements with the median of 2 meters, whereas those with less stringent demands are in training and intelligence; 3) Overall respondents see FEED as being less useful for site-specific applications than for tasks that analyze more area. Generally, a large area analysis has relatively less precise accuracy requirements; 4) Correct representation of the overall terrain form is more important than the elevation at any one point. It should be noted, however, that FEED was used for evaluating forward observer locations and monitoring target locations at HELBAT VIII. Its performance was viewed favorably and FEED participation has been requested in future HELBAT exercises.

The goal of assessing the accuracy of the data and graphics output was achieved only partially in a subjective sense and not at all in a quantitative sense. No procedures were developed to measure and analyze errors. Graphics output was usually compared to maps, especially with overlays at scale. Small features frequently were in error because of data resolution; however, in the experiences of EES the overall surface trends were always correct.

It is probably unrealistic, considering all events happening on the FEED tour, to expect that data accuracy could also be assessed. Accuracy is a function of several variables, including 1) the data resolution (horizontal spacing between sample points), 2) the order of the polynomial and the number of sample points used to create the polynomial, and 3) the texture of the actual surface. Both West Point[8] and ECAC[9] have published studies evaluating the accuracy of the polynomial terrain model, and the reader is referred to these studies for more detailed information. Accuracy is a valid aspect to evaluate, but was not a goal of the FEED demonstration tour.

3.0 TECHNICAL EVALUATION

A technical evaluation of FEED involved problem identification in each of three functional areas: hardware, software, and data. Refer to table 5, System Problem Summary, for a synopsis of the problems and suggested solutions discussed below.

TABLE 5. System problem summary

	PROBLEM	SUGGESTED SOLUTION	COMMENTS
HARDWARE	Non-ruggedized disk	Replace with mil-spec disk.	Most hardware failures have been associated with disk - mobility seriously affected.
	Tektronix must serve dual function	Add low-cost CRT as terminal.	User interaction interferes with graphics - degrades system use.
	Execution speed	Upgrade CPU.	Specifications for time for analysis do not exist, but all users agree that processing was too slow - 1602A is ten-year-old technology.
	Absence of digitizer	Integrate digitizer capabilities.	Useful in relating digital elevation to standard map sheets.
SOFTWARE	Disorganized files	Separate directories, create utility directory.	
	Duplication in libraries	Restructure library scheme.	A much higher degree of organization and documentation is needed if complex software is to be maintained.
	Absence of documentation	Chart calling sequences & swaps; document all common areas.	
	System backup inadequate	Implement regular system backups.	Needed for quick restoration of software in field.
	Use of nonstructured programming language	Use FORTRAN FLECS enhancement.	Compatible with previous code - provides in-line documentation.

TABLE 5. System problem summary - continued

	PROBLEM	SUGGESTED SOLUTION	COMMENTS
SOFTWARE (Continued)	Operator interface crude	Implement menu-driven monitor & formatted screens & help function.	Ease of use crucial for system acceptance.
	Device-dependent code for graphics devices	Isolate graphics calls for device independence.	Provides capability to integrate new graphics devices or adapt to new environments.
	Execution speed	Use optimizing compiler & I/O enhancements.	
	Size	Implement extended memory.	
DATA	No data-capture capability	Investigate requirements for input data standards.	DMA is data source.
	Limitations of single variable	Add land-cover data, slope, soils.	Importance of slope, soils, vegetation characteristics identified by demo participants.
	Accuracy of Level I data	Investigate trade-offs between data compression & spatial accuracy.	100-meter resolution can skip important features.
	Absence of data file documentation	Precisely specify all data file layouts & data flows.	Effectiveness of software maintenance depends on this.
	No procedures for handling multiple data sets	Establish procedures for naming, storing, moving, cataloging data sets.	

3.1 Hardware Problems

The FEED equipment is ruggedized with the exception of the CDC 80 Mb random access disk. Most reliability problems encountered in the FEED demonstrations were related to the CDC disk drive. While the CDC 80 megabyte drive is basically a good storage unit, it was not designed for rugged operation and could not be expected to withstand the jolting of cross-country travel without problems occurring.

The Tektronix graphics display terminal serves dual functions that often impede each other. The use of the screen for both graphics output and operator interaction requires an awkward separation of actions. Graphics output cannot remain on the screen for analysis without becoming cluttered with operator prompts and inputs. Similarly, the effectiveness of the thumbwheel cursor for enhanced operator interaction is greatly diminished.

One of the limitations of FEED most noted by demonstration participants is the time necessary for the computer to produce the analysis once the input parameters have been specified. The execution speed of the central processing unit is the primary limitation that causes slow turnaround of user-specified output products.

Although no standard for acceptable time for product generation has been specified, a faster turnaround time would be helpful. Comparison with manual methods obviously favors FEED; the automated products are certainly produced many times faster than comparable products manually produced. Nevertheless, generating and plotting maps at the demonstrations occupied too much time to hold participants' attention. The attention span of demonstration guests does not necessarily relate to any production time standards. An evaluation is needed by specialists such as terrain analysts and intelligence personnel to specify the requirements for operational product generation.

FEED's processor is a ROLM 1602A sixteen bit minicomputer, which incorporates 10-year-old hardware design and 15- to 20-year-old technology. The technology now exists for a large jump in capability within the ruggedized family of computers.

A commercial digitizing tablet was purchased for incorporation into the system. However, it was determined that it was impractical to hook it to the mil-spec CRT. The absence of the digitizer tablet limited the capability of the FEED system. The digitizer would be exceptionally useful in entering geographic locations and boundaries and in relating the digital elevation maps to standard map sheets. In areas where no digital terrain data exist, the tablet would have provided a means of entering high resolution photography and feature overlay maps for analysis.

3.2 Software Problems

The FEED computer software is a very large and intricate set of programs developed to perform extensive topographic analyses. It is imperative that an improved level of software organization and documentation become standard.

Currently, all the source programs, including over 100 separate programs, subroutines, and functions, are maintained in one RDOS directory along with old versions of the programs and with the data files. Duplications and use of wrong program versions are inevitable, causing delays and introducing bugs.

The library file structure is currently established in such a way that the same routine can be found in any of several different libraries. Again, duplication and confusions are the result.

The lack of software documentation and organization severely impedes the ability to correct, update, and modify the system. The lifespan of such a complex system invariably covers the assignment of many different individual software professionals. A clear path through the maze of programs, algorithms, overlays, and data is essential if problem areas are to be pinpointed quickly, if enhancements are to be made without disrupting existing code, and if size and speed requirements have to be evaluated for change.

The lack of procedures for regular system backup did result in delays and/or loss of more recent software changes.

Use of a nonstructured programming language complicates programming logic and software maintenance.

The interface between the computer software and the operator must be further enhanced. The handiness and ease of using the system for the operation must be considered very important, just as the technical accuracy of the products is obviously emphasized. If the system lives up to its proponents' time-saving claims by facilitating analysis tasks, even encouraging further investigations otherwise too toilsome or time-consuming, acceptance is insured. A primary goal must be to provide adequate richness of detail in analysis while reducing the degree of complexity facing the user.

Presently, much device-dependent software is operating to control output to the Tektronix and Versatec devices. Software should be device-independent to the greatest degree possible. Device independence means the degree to which the software is able to output to many different graphics devices whose operational characteristics are likely to vary considerably. Device independence provides for considerable flexibility in system configuration.

The need for improved system execution speed has been identified in Section 3.1 under hardware considerations. Software improvements can also be made to affect execution speed.

Many of the FEED programs are quite large (relative to currently available memory) and fit in memory only because overlaying has been implemented. Introduction of all enhancements and modifications must take these size constraints into consideration. In addition, the operating system currently restricts the use of existing memory in the system. Even though the ROLM has a memory complement of 64 kilowords, the operating system was never designed to allow more than one user to interface with the system and this does not allow the extra 32 kilowords of memory to be used as extended memory for program or array storage.

3.3 Data Problems

The source of elevation data for FEED is DMA. A potential problem is the absence of data-collection capabilities within the FEED system and the dependence on an external agency. It should not be inferred that any difficulties nave occurred as a result of the arrangement; they have not. Ideal systems, however, should have data collection as one function, or at least should have some administrative control over the process. FEED has neither. DMA produces data for many end users and does not set its standards for FEED. This condition could inhibit FEED developers from satisfying specific user applications that require different standards.

The ability to overlay other data sets for spatial association analysis is a powerful tool in geoprocessing systems, but it is here that the FEED system is at its weakest. FEED is essentially a single variable system and its analysis capability is limited to the information content of that variable. Many demonstration participants indicated that other sources of data such as land cover, vegetation height, and soils information would be extremely useful in evaluating mobility through the terrain. While it was felt that some justifiable analyses could be done with elevation data alone as a first approximation to the solution, most felt the need for more data in a fieldable computer system.

In some cases the accuracy of the elevation data used in the demonstrations was not sufficient to meet a particular user's needs. The data normally used in FEED demonstrations were Level I data provided by the Defense Mapping Agency (DMA). These data were coded from 1:250,000-scale topographic maps and are limited to the vertical accuracy of that map. For detailed sighting studies and other site-specific analyses the vertical accuracy is not sufficient. Level II and Level III DMA elevation data would be required for these tasks. Unfortunately, Level III data have only been collected over experimental test areas and are not generally available; it would require significantly more processing to produce a desired result; and because of limits in disk data storage, the detail provided by high resolution data involves the sacrifice of the spatial extent that a generated scene can cover.

Documentation of data files is not sufficient. Software maintenance and enhancements are complicated by the lack of data file documentation. Error recovery from problems with the several data, parameter, and swap files is not effective enough.

Procedures are not sufficient for handling multiple data sets. Improved data file management is needed.

3.4 Suggested Hardware Solutions

FEED's mobile configuration requires that a mil-spec random access disk system be procured to replace the CDC drive. A ruggedized 35.6 megabyte Winchester-type disk is currently available from ROLM. A Winchester disk is a hermetically sealed disk system that eliminates problems with dust in the operations environment.

Introduce into the FEED system a standard low-cost input/output cathode ray tube (CRT) to handle program editing and operator interface. The CRT would free the Tektronix for graphics display simultaneous with operator interaction as well as provide for input of coordinates by use of the thumbwheel cursor.

Specify the time requirements for an operational digital elevation product generation. Using these specifications, upgrade the central processor from the ROLM 1602A to a ROLM 1666 or ROLM MSE/14 or MSE/25. Each of these systems would operate on 1602A FORTRAN code without modification and would provide significant advantage in performance.

Integrate a digitizer tablet and appropriate software into the system as a data input device.

3.5 Suggested Software Solutions

As a first step in improving the software organization, a scheme should be implemented placing the main programs in separate directories, linking them to a utility directory that contains exactly one copy of the routines they have in common, and linking them to a separate area where the data would be kept. Printed listings of the current software should be maintained in one central notebook.

The library file structure should be reorganized to eliminate the duplication among routines. When any routine is changed, it should be clear which library should be updated and which programs will be affected.

Complex software that utilizes many programs, extensive overlays, program swaps, and data work files must be accompanied by a clear chart of organization. Such a chart should indicate all the program calling sequences, program swaps, and disk file names needed in operation. In short, this chart would be a picture of "who is doing what to whom." Additionally, all COMMON blocks should be documented to show what variables are included, what they are used for, and which routines share them. One possible effective scheme for standardizing COMMON blocks is to maintain all COMMON's in one disk file and use an INCLUDE-like statement to locate the appropriate COMMON in each routine.

A regular procedure to back up the disk to tape should be implemented to protect all software and provide for quick restoration of the software in the field as necessary. A backup disk pack should also be standard in case of a physical error on the primary pack.

The programs can be far more effectively maintained if they are converted to a structured language rather than using conventional FORTRAN. The FLECS structured software package, originally developed at Oregon State and available at Georgia Tech and elsewhere, offers many advantages over standard FORTRAN. For example, FLECS 1) produces FORTRAN code that is fully compatible with most FORTRAN compilers currently available, 2) is able to accept FORTRAN as input so that modifications to FEED software would not require massive, immediate changes, 3) can run on current FEED equipment and on any future proposed equipment, and 4) provides structured programming that is easier to maintain and add to later on. A well-written FLECS program can be virtually self-documenting. A FLECS user's manual is available as a Georgia Tech report.[10]

3.6 Suggested Data Solutions

Studies should continue to investigate the requirements for input data standards for FEED and FEED-like systems. Requirement specifications are essential for proper design and implementation of all enhancements. Specifications must be garnered from field experience as to the precision required for operational acceptance. These requirements could then be inserted into FEED data handling and software development procedures.

A significant modification would involve upgrading the FEED system to utilize multisource data. In addition to elevation data, the system would be able to support a geographic data base in which each layer of the data base consists of a spatial variable. Land-cover data and soils-related data would each be a layer in the geographic data base. An overall geographic data base handling package would be implemented to allow combinations of multiple variables to perform analyses such as mobility across terrain.

The second modification would allow LANDSAT land cover data to be implemented as one layer in the data base. The current LANDSAT resolution is approximately the same as that for Level I DMA topographic data, and LANDSAT data are available worldwide. Many analyses could be done in any region of the world using only the generally available Level I data and LANDSAT data. The LANDSAT data would need to be preprocessed to generate land-cover classes and their topographic offsets and geometrically rectified to map coordinates to overlay the DMA elevation data. It should be noted that LANDSAT D (launched in the summer of 1982) will provide spatial resolution four times as good as that of the existing LANDSAT data.

Specifying and recording all data file structures will enhance software maintenance and development. All data flows should be traced through the programs. This type of documentation will naturally be closely related to the documentation of the COMMON blocks suggested previously in the section on Software. Pretesting for existence of the needed execution work files will provide graceful error recovery in their absence.

Improved data file management can be obtained by establishing procedures for naming, storing, moving, cataloging, and archiving all data sets.

4.0 FEED ALTERNATIVES

USAETL has several directions in which it can go in deciding the fate of the FEED program. Some of the following alternatives can be modified by combination with another alternative. The major options available are to

1) Upgrade FEED software and hardware and use it to elicit user comments and recommendations from the Field Army to be used in the design of advanced digital terrain systems. Ways to achieve this goal are

   a. Allow an upgraded FEED-type system to participate in field operations.
   b. Implement a FEED-like system to be used by an operational topographic unit for training and user responses.
   c. Develop a non-mil-spec, low cost version for training.

2) Field FEED as it is, if requirements documents for it come forth from the demonstrations.

3) Dismantle FEED and continue doing research and development within ETL.

If the option is chosen to upgrade FEED software and hardware so that it can provide user input into the design of advanced digital terrain systems, a number of factors need to be considered. Initially, the FEED system should be withdrawn for a period of 3 to 6 months so that the software structural modifications and detailed documentation could be completed. A priority list for software implementation should not occur until the documentation is complete. After the initial restructuring of the software, the system should be tested by Field Army personnel while new modules or capabilities are being developed on a parallel configuration. The response from the field exposure should be factored into the overall design concept.

If it is decided to allow the FEED system to participate in ongoing field operations such as HELBAT and REFORAGER, at least some of the hardware upgrades should occur before initiation of the exercise. Since field operations are normally held in circumstances approaching a battlefield environment, a system to be used in such an exercise should be moveable and able to withstand rough treatment; therefore, at least the ruggedized Winchester disk should be implemented into the system configuration. To make the FEED system more readily transportable it is suggested that the system hardware and retaining structure be designed to fit on a loading palette. If many requests are received for FEED participation in field operations, several FEED-type configurations might be assembled. The overall purpose for the participation in field operations would be

1) Pseudo-operational digital elevation data analysis in the field

2) Demonstration of spatial data base analysis, as the computer programs for that analysis become available, and

3) Accumulation of user comments and suggestions to be used in design of advanced digital terrain systems.

One other way in which to consider user comments as to the usefulness and effectiveness of a FEED-type system would be to allow regular use of a system by a unit in the field. If the system were used to plan and execute maneuvers jointly with combat arms units in the field, the resulting experience gained by topographic battalion personnel would be extremely valuable in the design of future systems. In addition, all involved units would come to understand the basic limitations of some computer-driven systems and the advantages of others. Since many weapon systems are now being developed that are driven by a computer topographic analysis such as TERCOM (for terrain matching along a flight path), and since the upgraded software for a FEED-type system is inherently easy to use, FEED could provide insight for the soldier using such a sophisticated guidance scheme.

For training and evaluation of FEED-type systems, the mil-spec version of FEED might not be necessary. A low cost (90K) minicomputer system could demonstrate all FEED objectives except field implementation. If several FEED-type systems are desired for different regions of the country or for different applications, the less expensive version might suffice.

If the FEED demonstrations result in a hard requirement for a digital analysis system that considers only elevation data, a system such as FEED might be able to satisfy that need with some modifications. As discussed in the previous sections, the basic set of software and hardware are usable but not optimum in their present form. A fully mil-spec system, however, would be needed for fielding.

If the third option is selected, FEED will be dismantled and work that is already in progress will continue toward developing an advanced digital terrain analysis system.

5.0 FEED RECOMMENDATIONS

The Engineering Experiment Station feels that a FEED-type system can be used to prepare the way for easier acceptance of future digital terrain systems. By using a precursor to such a system that will operate on currently available data with currently available hardware, Army personnel will acquire "hands-on" training in the use of digital elevation data and will begin to learn of the power of spatial analysis using several variables.

1) Studies should immediately be performed to

   a. define accuracy and timing necessary for a limited set of specific applications
   b. investigate the use of publicly available LANDSAT data to indirectly provide estimates of vegetation cover and heights
   c. investigate state-of-the-art hardware that would reduce processing time for FEED functions.

2) Documentation of FEED software should proceed immediately. Documentation should include

   a. programmer's reference manual
   b. in-code documentation.

3) A followup action should proceed immediately to gather information from FEED tour participants.

4) An upgrade of FEED capabilities should be initiated including

   a. software upgrades for
      (1) Implementation of overall Driver Structure for FEED
      (2) Implementation of secondary data (such as land cover) to provide elevation offsets for FEED analyses
      (3) Implementation of a digitizing system for local data input
      (4) Implementation of a grid-base, multisource data analysis system

   b. hardware upgrades
      (1) Replace CDC disk with militarized Winchester-type disk
      (2) Implement digitizer and alphanumerics terminal
      (3) Upgrade CPU to appropriate militarized higher speed system.

5) FEED should be allowed to participate in field operations that enable ETL to gather information as to the system's usefulness as well as giving field units an opportunity to better evaluate the FEED. For field operation participation:

   a. An effective questionnaire must be developed to provide adequate information for FEED evaluation.
   b. The agency/unit in charge of planning the field operation should define specific tasks that will be attempted using FEED.
   c. A plan for accomplishment of these tasks should be detailed by the unit in charge and ETL personnel.
   d. A plan for evaluation of results must be defined to determine success or failure for specific tasks and to collect appropriate data.

REFERENCES

1. James R. Jancaitis, and John L. Junkins, ETL-CR-73-4, Mathematical Techniques for Automated Cartography, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va., February 1973, AD 758 300.

2. Thomas O. Tindall, "Experimental Field Exploitation of Elevation Data (FEED)," Army Research, Development, and Acquisition Magazine, September-October 1980.

3. John J. Charland, The DMA/ETL Research Project: Computer Graphics for the Army, U.S. Military Academy, West Point, N.Y., June 1981.

4. John E. White, The Field Exploitation of Elevation Data (FEED) Model, ITT Research Institute, Annapolis, Md.

5. USAETL, FEED (Field Exploitation of Elevation Data) Prototype System, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va.

6. USAETL, Tech Tran, Vol. 6, No. 2, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va., Spring 1981.

7. USAETL, OPORD-FEED-ETL, 1309004, February 1981.

8. Charland, op. cit.

9. R. J. Jablinske, "Polynomial Modeling Versus Conventional Matrices in Terrain Data Applications," IIT Research Institute under contract to Electromagnetic Compatibility Analysis Center, Annapolis, Md., April 1979.

10. Douglas E. Wrege, FLECS User's Manual, Georgia Institute of Technology Engineering Experiment Station, Atlanta, Ga., 1978. Adapted from the original manual written by Terry Beyer, University of Oregon, Eugene, Oreg.

Appendix A

FIELD EXPLOITATION OF ELEVATION DATA (FEED) QUESTIONNAIRE

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

FIELD EXPLOITATION OF ELEVATION DATA (FEED) QUESTIONNAIRE

1. Service: USA ✓ USMC___ USAF___ OTHER___
2. Grade: G.O.___ Field Grade___ Company Grade___ NCO___ Enlisted ✓
3. Branch/Specialty: (Engineer/Combat Development) Military Intell
4. Would terrain data be useful to your mission accomplishment: YES ✓ NO___
5. In what areas?

	YES	NO
a. Training		✓
b. War Gaming		✓
c. Mission Planning	✓	
d. Mission Execution	✓	
e. Other:		

6. How would it be employed?

	YES	NO
a. Terrain Appreciation/Orientation	✓	
b. Sensor Emplacement		✓
c. Intelligence Preparation of the Battlefield	✓	
d. Weapons Siting		✓
e. Flight Operations		✓
f. Other:		

7. For a computer-assisted graphics system like FEED to be useful (4–6 above), what characteristics should it have?

a. Graphics:

	YES	NO
Line of Sight	✓	
Terrain Masking	✓	
Contour Plot	✓	
Perspective View	✓	
Oblique View	✓	
Military Features	✓	
Movement	✓	
Site Selection	✓	
Other:		

b. Accuracy:

Elevations	(Z)	+	10 m
Locations of Features	(X, Y)	+	10 m
Other:			

c. Performance:

Produces graphics within (time)

60 minutes or 1 hours

d. Location:

	YES	NO
Training Sites	✓	
Battlefield	✓	
Down to what level?		
EAC		
Corps	✓	
Division	✓	
Bde		✓
Other:		
Where specifically?		
TOC		
Engr		
Aviation	✓	
Signal		✓
Arty	✓	
Other:		

8. Comments:

9. Date:

IF you are interested in further helping to develop a need/requirements statement for such a system, please complete below:

NAME: ______________________________

RANK: ______________________________

TITLE: ______________________________

Phone Number (A): ______________________

END

FILMED

9-83

DTIC